while raising the tail in excitement. Some components of behavior correspond to those of some other Mustelinae especially to those of *Martes martes:* embracing of play objects while lying on the back, play fighting, scratching with the hind legs in excitement, "mole-play".

The behavior of *Grisonella* corresponds also to that of some Viverridae, especially Herpestinae like *Herpestes edwardsi, Mungos mungo, Suricata suricatta:* attacking sound, invitation to play fighting, defense posture, scratching with the hind legs in excitement, going backwards "mole-play". This corresponding behavior suggests phylogenetical relations between the two groups though it is also possible that it is only caused by a similar way of life and similar body proportions.

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Anschrift der Verfasserin: Priv.-Doz. Dr. GERTI DÜCKER, Zoologisches Institut der Universität, 44 Münster, Badestr. 9

Faunal Sampling and Economic Prehistory

By C. F. W. HIGHAM

Eingang des Ms. 26. 7. 1967

Introduction

An analysis of the prehistory of stock rearing turns upon evidence of faunal samples from prehistoric settlements. Yet, despite the considerable number of reports on domestic animal bones from prehistoric settlements published in recent years, little attention has been paid to the sampling problems involved: deductions have often been made without due regard to possible sources of sampling bias.

The aims of this paper are two-fold: to consider the possibility of calculating the standard error for the estimate of the percentage frequency for a given species within a faunal spectrum, and to discuss the potential sources of sampling bias associated with the ranking of species in order of relative numerical importance. An analysis of the problems inherent in studying prehistoric faunal samples is necessary at a time when the aims and methods of prehistoric farming are becoming increasingly relevant to the interpretation of European prehistory.

The faunal spectrum of Egolzwil 4

VESCELIUS's assertion that archaeologists have, in the past, been content to assume that haphazardly collected grab samples are representative of artefact populations applies with equal force to faunal samples (1). In order to permit the estimation of the standard error for the percentage frequency of occurrence of a given trait within an artefact sample, VESCELIUS advocated cluster sampling. Unfortunately, this is not possible even in faunal samples obtained from recently undertaken excavations, since the manner in which samples were collected precluded cluster sampling analysis to be performed. Nevertheless, with certain reservations, it is possible to obtain the standard errors for the percentages of mammalian species from prehistoric settlements, and in the following description, Egolzwil 4 is taken as the type site.

Egolzwil 4 is a settlement of the Younger Cortaillod Culture situated on the northern margins of the former Wauwyl Lake in the Canton of Lucerne, Switzerland. The size of the village has not as yet been ascertained, but since 1952, an area of 1,300 square meters has been uncovered, and it would appear that at least 50 %, and possibly more, of the total area of the former settlement has been excavated. Four main building phases have been observed (2), the weight of the overlying lacustrine deposits having crushed the remains of each building phase into one undifferentiated culture level.

Excavations at this site cover not only the inhabited part of the village, but also an area devoid of houses towards the former lake shore. Concentrations of bones in the latter area evidence the existence of middens. The proportions of the bones of the four major domestic animals appear to be similar whichever midden, or part of the village, is considered. Moreover, roedeer bones appear to be nucleated, and in some such concentrations, the bones derive from the same animal. It appears reasonable, therefore, to suggest that roedeer bones at least, and possibly the bones of other species also, were deliberately deposited on the middens shortly after death.

At Egolzwil 4, an average of 1.85 species-identified bones have been found per square meter. Since, as VESCELIUS noted, it is preferable to have at least 50, and if possible more than 100, specimens per "cluster" or unit area, the excavated part of the site has been subdivided into a total of thirteen such unit areas, each 100 square meters in extent, and containing on average 241 bones.

There are, therefore, a number of modifications to an ideal investigation of a cluster sample as outlined by VESCELIUS. Foremost, the areal extent of the village is unknown. It is assumed to have been twice as large as the area excavated. It may be more, or may be less. Secondly, the unit areas are not selected from the site at random: the whole excavated area has been divided into 13 such entities.

It is possible, however, to define limits for the estimate of the standard error by calculating three separate values, in which it is assumed that 10 %, 50 % and 90 % of the entire settlement has been excavated. Of course, when more of the settlement has been uncovered, it will be possible to have available sufficient unit areas to be able to select some at random, and perhaps modify the conclusions derived from the present study.

The number of species identified bones per unit area are seen in Tables 1 and 2. The means and standard errors of the frequencies with which the bones of domestic cattle, swine, sheep or goat, red deer and domestic animals combined occur, are seen in Table 3. The results indicate that a low standard error is in question. Assuming that only 10 % of the settlement has been excavated, the chances are 2:1 that the true bovine percentage lies between 28.5 % and 32.5 %, and 20:1 that the true fraction lies between 26.5 and 34.5 %.

It is thus observed that the greater the percentage of the settlement excavated, the lower the resultant standard error. At Egolzwil 4, a site yielding upwards of 2,000 species identified bones, the magnitude of the standard error of the mean percentage of domestic animals is held to be low. Further estimates for other prehistoric faunal samples however, are needed to corroborate this finding.

It has been assumed that each anatomical bone within the bovine skeleton has an equal chance of being found by the excavator. Table 4 is a list of the major bones in the bovine skeleton, and the number of specimens of each bone actually found at Egolzwil 4, weighted of course, to take account of the fact that some bones occur in the skeleton more frequently than others. It is apparent that if each bone had an equal chance of being found, the number of each type of bone should not differ significantly from a mean

Table 1

Egolzwil 4: The Number of Species Identified bones in each of Thirteen 10×10 meter areas

Area	Bos taurus	Cervus elaphus	Alces alces	Bos prim.	Canis fam.	Capreolus c.	Castor fiber	Felis sylv.	Lutra lutra	Martes sp.	Meles meles	Ovis/ Capra	Sus dom.	Sciurus vulgaris	Sus dom./ ferus	Sus ferus	Total dom.	Total
1	137	103	0	18	11	15	6	9	0	2	13	29	74	1	15	21	251	454
2	131	85	5	18	2	11	12	2	0	1	4	27	78	0	9	16	283	404
3	33	29	0	9	9	1	6	0	0	0	0	13	13	0	2	4	68	120
4	25	17	0	1	8	2	0	0	0	0	4	4	10	0	2	0	47	73
5	59	62	0	5	5	4	1	0	1	0	12	26	25	0	6	6	115	212
6	33	21	1	4	0	1	1	0	0	0	0	0	5	0	0	3	38	69
7	11	9	0	1	0	0	5	0	0	0	0	6	8	0	1	1	25	42
8	48	31	0	3	5	2	11	0	0	2	4	7	16	0	1	2	76	134
9	57	39	0	12	12	4	5	2	0	0	10	14	20	1	2	4	103	182
10	49	41	0	5	0	2	0	0	0	0	3	18	25	0	0	4	92	147
11	121	91	0	18	0	22	5	0	3	0	7	82	112	0	10	19	315	493
12	5	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	7	9
13	25	7	0	0	1	1	0	0	0	1	0	8	25	0	1	1	59	71
Total	734	536	6	94	53	65	53	13	4	6	57	236	411	2	49	81	1 434	2 410

Table 2

Egolzwil 4: The Sample Sizes and Percentages of the Most Common Animals, per 10×10 meter area

Area	Number of bone fragments/area	% Domestic bovines	% Swine	% Sheep/Goats	% Red Deer
1	454	30.2	16.3	6.4	22.7
2	404	32.4	19.3	6.7	21.0
3	120	27.5	10.8	10.8	24.2
4	73	34.4	13.6	5.5	23.3
5	212	27.9	11.8	12.3	29.2
6	69	48.0	7.2	0.0	30.4
7	42	26.2	19.0	14.3	21.4
8	134	35.7	11.9	5.2	23.1
9	182	31.4	10.9	7.7	21.4
10	147	33.4	17.0	12.2	27.9
11	493	24.5	22.7	16.6	18.4
12	9	55.8	0.0	22.2	11.1
13	71	35.2	35.2	12.7	9.8
$\bar{X}$	241	30.5	17.0	9.8	22.2

frequency of about 13. The value of X^2 on comparing the actual and mean numbers of bones is 220.7, which is highly significant. Furthermore, the number of mandibles and teeth attest at least fifty individual animals, a number not matched by the limb bones. It is thus clear that a differential bias operated on the frequency with which bones have been found.

There are a number of potential reasons for this finding that faunal samples are biased in one or more respects: there is the original bias of the stock rearer for what was considered to be the most favourable portion of his herds for the provision of food and basic raw materials. In the last analysis, it is this bias which most concerns the prehistorian when studying faunal remains. It may however, be clouded with other sources of bias. Thus KURTÉN has observed that the immature skulls of the Dall Mountain Sheep are more fragile than adult specimens (3). The slender bones of rodents, birds and fishes are also relatively fragile: the presence of nets and net sinkers

Table 3

Egolzwil 4: The Percentage Frequencies of Occurrence of the bones from named species together with the standard errors on their frequencies, upon the assumption that 10%, 50% and 90% of the site has been excavated

	%	S. E. (10 %)	S. E. (50 %)	S. E. (90 %)
Bos taurus (domestic)	30.5	2.0 %	1.5 %	0.20 %
Sus scrofa (domestic)	17.0	2.0 %	1.5 %	0.20 %
Ovis/Capra	9.8	3.2 %	2.4 %	0.34 %
Cervus elaphus	22.2	1.6 %	1.2 %	0.17 %
total of domesticated animal bones	60.9	2.1 %	1.6 %	0.23 %

Table 4

Egolzwil 4: The Numbers of given anatomical bones from bovines

Bone	Number	No. of such bones in one skeleton
Mandible	79	2
Maxilla	19	2
Premaxilla	4	2
Skull fragments	29	—
Horn Core	15	2
Scapula	30	2
Humerus	47	2
Radius	46	2
Ulna	16	2
Magnum	6	2
Unciform	3	2
Scaphoid	5	2
Lunate	7	2
Metacarpal	42	2
Fore phalanx proximal	8	4
Fore phalanx middle	10	4
All phalanges distal	13	8
Pelvis	28	2
Femur	18	2
Tibia	29	2
Patella	6	2
Calcaneum	14	2
Astragalus	18	2
Os malleolare	1	2
Lateral cuneiform	2	2
Metatarsal	32	2
Rear phalanx proximal	12	4
Rear phalanx middle	13	4
Hyoid	3	1
Cuboid/Navicular	12	2
Pisiform	2	2
Total	404	
Mean	12.62 per anatomical bone	

in some Swiss prehistoric settlements attest fishing where fish bones are notable for their absence. The presumptive bias in favour of the mature bones of large animals should however, not be stressed, for the mandibles of unweaned red deer have been found at Egolzwil 4. Such bones could have been preserved intact by their surrounding ligaments until protected from the elements by other objects cast onto the middens. Nevertheless, even under the most meticulous supervision, there is a potential bias in favour of large bones being found.

The presence or absence of gnaw marks on bones made by dogs appears to be culture conditioned, for whereas bones from the Cortaillod Culture sites are normally free from gnaw marks, many bones from the Egolzwil Culture site of Egolzwil 3 are not. A powerful dog can easily crush and consume small bones, and in fragmenting large ones, increase the number of species identified fragments from a given site.

A further potential source of bias results from the fact that different anatomical bones have different quantities of attached muscle. Therefore, the femora or humeri, which have much attached meat, are likely to have been broken and rendered unidentifiable. The phalanges however, having little, may often be found complete. Moreover, the small and compact phalanges are more likely to survive than the fragile articulating ends of the femur. As White (4) has shown in his study of the faunal remains from the Plains Indians settlements, only select cuts of meat were brought from the kill to the home village. The same phenomenon could well have taken place during the prehistoric period in Europe, thus distorting the proportion of domestic to wild animal bones. Two facts however, indicate that this source of bias may be slight. The Plains Indians hunted bison on horseback, thus travelling many miles from the home settlement in pursuit of an unusually large animal. Under such circumstances, it was impraticable to take home more meat than was actually required. In Europe during the neolithic period, however, wild animals, with the exception of the auroch and bison, were smaller than the Plains Bison, were not hunted on horseback, and were probably dismembered close to the home village.

These are among the major potential sources of bias. It is evident that no collection of prehistoric bones is a random sample of the bones from the animals comprising a society's domestic herds. What is required for the purposes of the prehistorian is an estimate of the relative importance of the mammalian species used by different societies for their economic requirements.

The commonest method of estimating the relative frequencies of different species at prehistoric settlements is first to sum the number of species identified bones and then to express the number of bones ascribed to each species as a percentage of the total. In some cases, however, when the size of the bone sample from each of a number of sites from the same culture has been small, then the samples have been pooled and relative frequency of each species defined on the basis of the combined sample (5). A second method of ranking the relative frequency of species in a faunal sample is to estimate the number of individuals represented by the bones themselves. In the present investigation, both these methods have been used for the analysis not only of the material studied by the present author, but also that described in the literature (Table 5).

From Table 5, it will be noted that the relative proportion of bovines calculated from the number of bone fragments only is, in nearly every case, higher than that calculated from the number of individuals actually represented. The opposite situation obtains for caprovines, while both methods provide similar estimates for the frequency of occurrence of swine. In some cases, the discrepancy between the percentage frequencies for each animal on the basis of them two methods reaches major proportions. Thus the percentage of bovines at Lindø is 52.5 on the basis of the number of identified bones, but only 26.0 on the basis of the number of animals represented. Furthermore, the number of bone fragments in the sample has no discernible effect on the magnitude of the observed discrepancy. Indeed at Manching, with a sample size of 118,510 bone fragments, the discrepancy is greater than a Györ-Papai Vam, with a sample size of only 224 specimens.

Since the two methods of estimating the relative frequencies of animal species from prehistoric bone samples give consistently divergent results, the advantages as well as the disadvantages of each will be considered in the light of the potential sources of bias discussed above.

Now the juvenile humerus comprises diaphysial and epiphysial bones, and the juvenile pelvis comprises the sacrum, ilium, pubis and ischium. In both cases, these distinct entities fuse at a given age, to form one bone. Therefore, a humerus and a pelvis from a juvenile animal will disarticulate into at least nine distinct bone fragments, whereas corresponding bones from an adult will not. If a particular society killed some cattle when six months of age, but maintained all sheep until fully mature, the ratio of cattle to sheep bones will not correspond to the actual number of animals killed.

In seeking bone marrow, or in disarticulating a carcass to facilitate the removal of meat, bones are perforce fragmented. Consequently, the fragmentation of complete bones could lead to a bias against smaller-boned species. The fact that small bones may be more easily overlooked by the excavator than large bones may account for the rarity of ovine, compared with bovine, carpal bones in nearly all faunal samples examined by the author. Indeed, exceptionally sophisticated excavation techniques are necessary to discover the small anatomical bones of rodents or birds. Therefore, if the number of bone fragments from prehistoric settlements is used as the basis for ranking species in relative order of importance, it should be remembered that a bias may decrease the actual importance of small, and thus increase the importance of large, species.

Scavenging dogs may crush and consume small bones, but only split and gnaw large bones. Again, therefore, the relative importance of small animals may be arti-

Table 5

The percentages of the common domestic animals from prehistoric settlements, in terms of the total number of bone fragments and the number of individuals represented

Site	Total No. of Fragments	Estimated No. of Individuals	Estimated % Cattle		Estimated % Swine		Estimated % Sheep/Goat		Author
			Fragments	Individuals	Fragments	Individuals	Fragments	Individuals	
Egolzwil 4	2 531	244	28.7	20.5	14.9	22.2	10.3	18.4	Higham
Arbon Bleiche	2 794	237	65.1	40.5	21.2	27.5	8.1	24.0	Higham
Seeberg (Burgäschisee-Süd)	17 419	421	1.9	2.1	1.44	5.5	1.2	4.8	Boessneck
Zürich Utoquai (Horgen)	554	45	16.4	15.6	31.8	24.5	8.3	11.1	Higham
Troldebjerg	19 894	660	37.8	29.7	50.7	51.6	10.3	13.3	Higham
Zürich Utoquai (Corded Ware)	257	28	51.0	32.2	21.8	14.3	8.5	14.3	Higham
Voldtofte	2 030	159	68.8	53.6	19.0	27.0	8.4	16.4	Higham
Zürich Breitingerstraße (Michelsberg)	385	32	54.0	40.6	17.4	15.7	1.3	6.3	Higham
Egolzwil 3	393	51	1.2	2.1	7.3	8.5	32.9	29.9	Higham
Bundsø	2 428	155	36.5	35.5	42.0	26.0	11.5	22.0	Higham
Lindø	1 188	100	52.5	26.0	27.2	33.0	15.8	26.0	Higham
Veileby	7 124	407	43.0	29.5	25.7	35.3	23.6	30.3	Higham
Zug Sumpf	804	71	22.5	15.5	15.4	16.8	51.8	50.9	Higham
Eschner-Lutzengüetle (Schussenried)	1 158	127	57.0	33.0	18.1	20.5	19.4	29.9	Hartmann-Frick
Eschner-Lutzengüetle (Michelsberg)	1 823	229	49.6	30.6	17.5	15.6	20.0	35.4	Hartmann-Frick
St. Aubin IV	276	—	31.8	18.7	14.8	13.7	20.7	28.2	Reverdin
Manching (1955)	118 510	2 626	43.7	26.7	32.4	34.3	19.0	30.5	Boessneck
Györ-Papai Vam	224	136	66.0	57.4	10.7	11.7	13.5	17.7	Bökönyi

ficially low, a finding which confirms that the total number of bone fragments belonging to different species in a prehistoric bone sample could give a misleading picture of the relative importance of each species at that site.

In the alternative method of estimating the relative number of each species in a faunal sample, the number of individual animals represented by bone fragments must be calculated. In theory, this would necessitate an estimation of the number of individuals represented by each anatomical bone, but in practice, the highest number of individuals is almost invariably supplied by the mandibles and teeth. The method of calculating the number of individuals represented is described in the appendix to this article.

The method of calculating the relative importance of each species by the number of individuals represented may be biased by the greater fragility of immature compared to mature mandibles. Yet the mandibles and teeth appear to have a greater degree of durability than most limb bones. Indeed, the complete mandibles of foetal or newly born red deer have survived at Egolzwil 4. Therefore, assuming that a particular society killed many sheep when under six months of age, but maintained all their bovines until fully adult, an estimate of the number of individuals represented by the mandibles and teeth would be expected to give a more accurate approximation to the relative importance of each species than would the sum total of the number of bone fragments assigned to either species.

A further source of bias which may affect the estimate of the number of individuals represented by mandibles and teeth is the possibility that small specimens may be more easily overlooked by the excavator than large specimens. Nevertheless, of all bones, the mandible and dentition are the most immediately recognized, and the species of teeth can readily be ascertained. This potential source of bias therefore, is less likely to affect the estimate of the number of individuals represented than the total number of fragments assigned to each species, because in the latter situation, the magnitude of the bias will increase when small bones are included within the calculation.

The selective splitting of certain bones could increase the number of bone fragments ascribed to one species, but not another. The mandibles of cattle and swine, for example, appear to have been split to obtain their marrow at most sites, whereas those of sheep, being smaller, are often found intact. This finding would result in there being more cattle than sheep bones in a situation where the number of individual animals is identical. Now it is possible to estimate the number of individual animals present from a combination of fragmentary and complete mandibles. Therefore, this source of bias does not affect the estimate of the number of individuals represented.

One of the purposes of this study is to define the most logical method of ordering the relative importance of cattle, sheep, goats and swine in the economies of a number of prehistoric cultures. This evidence is provided by the actual bone remains of the species in question. It has been demonstrated, however, that there are a number of sources of bias operating on the frequencies with which the bones are found, and as a result, the two methods of ranking the four species in their frequency of occurrence give divergent results. Thus, if every bone of every animal killed was found by the excavator, the estimation of the relative importance of each species would present no difficulty. With every bone that has disintegrated, fragmented, or been overlooked since the parent animal was killed however, the ideal situation in which every bone of every animal is found becomes increasingly remote. Indeed, a situation could arise in which the number of bones ascribed to each species gives a misleading picture of their former relative importance. The method whereby the number of individual animals represented by the bones of each species has also been shown to be open to sampling bias, but to a considerably smaller extent. Consequently, this method is advocated for use in prehistoric bone samples.

Conclusions

An analysis of the disposition of animal bones at the neolithic village of Egolzwil 4 has revealed the presence of select middens, which were located away from the main settlement area. The excavated part of the site has been sub-divided into 13 unit areas, and the variability of the relative importance of the various species within each unit area has been considered. Little variation has been found from one unit area to another, a situation reflected in the low standard error for the percentage of the total number of species identified bones accounted for by each species.

On comparing the relative numerical importance of each species at a number of prehistoric settlements on the basis of two methods in current use, widely divergent results have been obtained. A consideration of the main potential sources of sampling bias involved has been presented, and it is concluded that the ranking of species on the basis of the number of individual animals represented by bone fragments is the more valid method.

Zusammenfassung

Eine Analyse der Ablagerungen von Tierknochen bei dem neolithischen Dorf Egolzwil 4 erwies das Vorhandensein von ausgesprochenen Abfallhaufen, die von der Hauptsiedlung entfernt angelegt waren. Der ausgegrabene Teil der Lagerstätten wurde in 13 gesonderte Abschnitte aufgeteilt, und die Unterschiede in der relativen Wichtigkeit der verschiedenen Arten innerhalb jeder dieser Einheiten untersucht. Geringe Unterschiede nur wurden von Einheit zu Einheit gefunden, eine Situation, die sich auch wiederspiegelt in dem geringen Standard-Fehler für den Prozentsatz der Gesamtzahl der Arten identifizierter Knochen, die jeweils den verschiedenen Arten zugerechnet werden konnten.

Ein Vergleich der relativen numerischen Wichtigkeit jeder Species einer Anzahl prähistorischer Siedlungen nach zwei verschiedenen gebräuchlichen Methoden erbrachte sehr verschiedene Ergebnisse. Es wird eine Übersicht gegeben über die allgemeinen potentiellen Fehlerquellen bei der Probenentnahme, und die Schlußfolgerung ist, daß die Rangfolge der Arten auf Grund der Anzahl Individuen, repräsentiert durch Knochenbruchstücke, die beste Methode ist.

Appendix

The following steps have been taken in computing the number of individual animals represented by mandibles and dentition from prehistoric settlements.

1. All mandibles, molars and premolars have been divided into right and left-hand groups and assigned a growth stage on the basis of dentition development.
2. Each left hand specimen has been compared with right hand specimens of the corresponding stage to see if could, on the basis of size, morphology and wear, be derived from the same animal as any right hand specimen. If so, it has been eliminated from consideration.
3. The maximum number of individuals per growth stage represented by left hand and by right hand specimens have been tabulated and considered jointly to evaluate the maximum number of animals represented per stage.
4. The number of individuals represented per stage has been summed for all stages to discover the total number of individuals represented in the sample as a whole.

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Authors address: C. F. W. Higham, Lecturer in Anthropology, University of Otago, Dunedin, New Zealand